



Improved Lyman Ultraviolet Astronomy Capabilities through Enhanced Coatings

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Outline



- ❖ Overview & Objectives
- ❖ Experimental details
- ❖ Results
- ❖ Conclusions

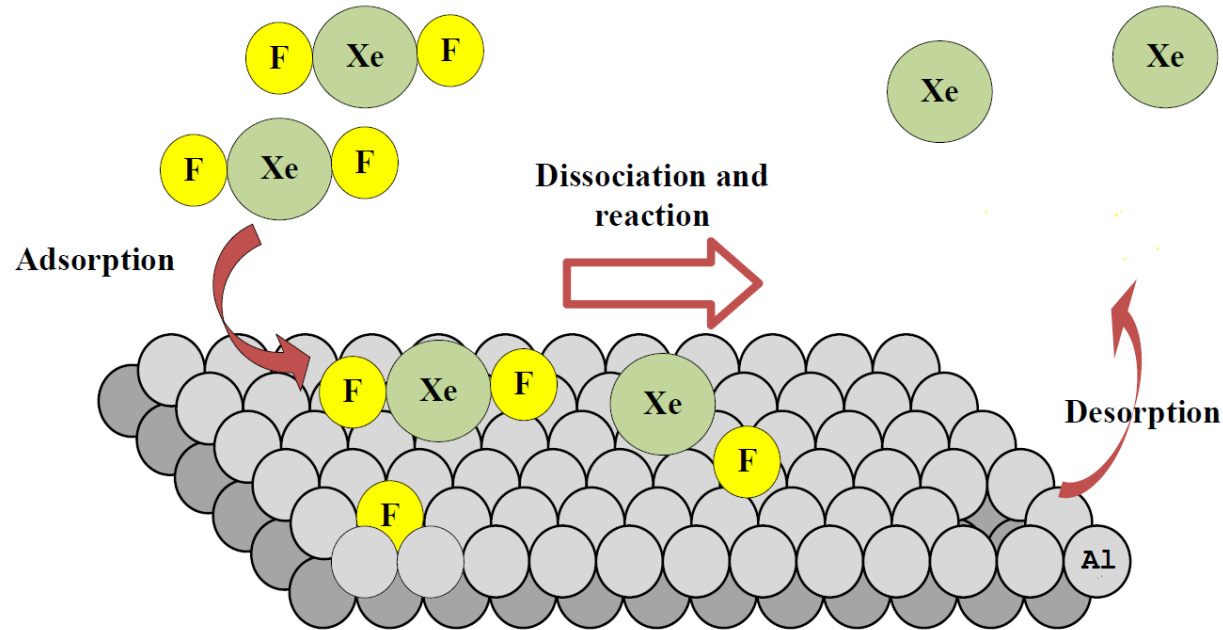


Overview and Objectives

- Summarized Task Description
 - Deposit high performance UV to FIR optical broadband coatings by designing/constructing hybrid thin film deposition/ fluorination chamber capable of depositing aluminum under ultra-high vacuum with the capability of adding a precursor gas to fluorinate the surface and form a thin layer of AlF_3 to protect the metal from oxidation.
- Driver / Need
 - High-performance broadband coatings (90-10,000 nm) have been identified as an “Essential Goal” in the technology needs for the Large UV/Optical/IR (LUVVOIR) Surveyor observatory.
 - Low reflectivity and transmission of coatings in the Lyman Ultraviolet (LUV) range of 90-130 nm is one of the biggest constraints on FUV telescope and spectrograph design.
- Benefits
 - By demonstrating new low-absorbing materials which can be used at a broadband, the technology will enable the merging astrophysics, solar physics, atmosphere physics, and optical exoplanet sciences with a shared telescope providing high throughput and signal-to-noise ratio (SNR) in the entire spectral range.



Hybrid PVD Passivation/Fluorination chamber



Reactive fluorine compound with low bond energy used (e.g. XeF_2 with 133.9 kJ/Mole)

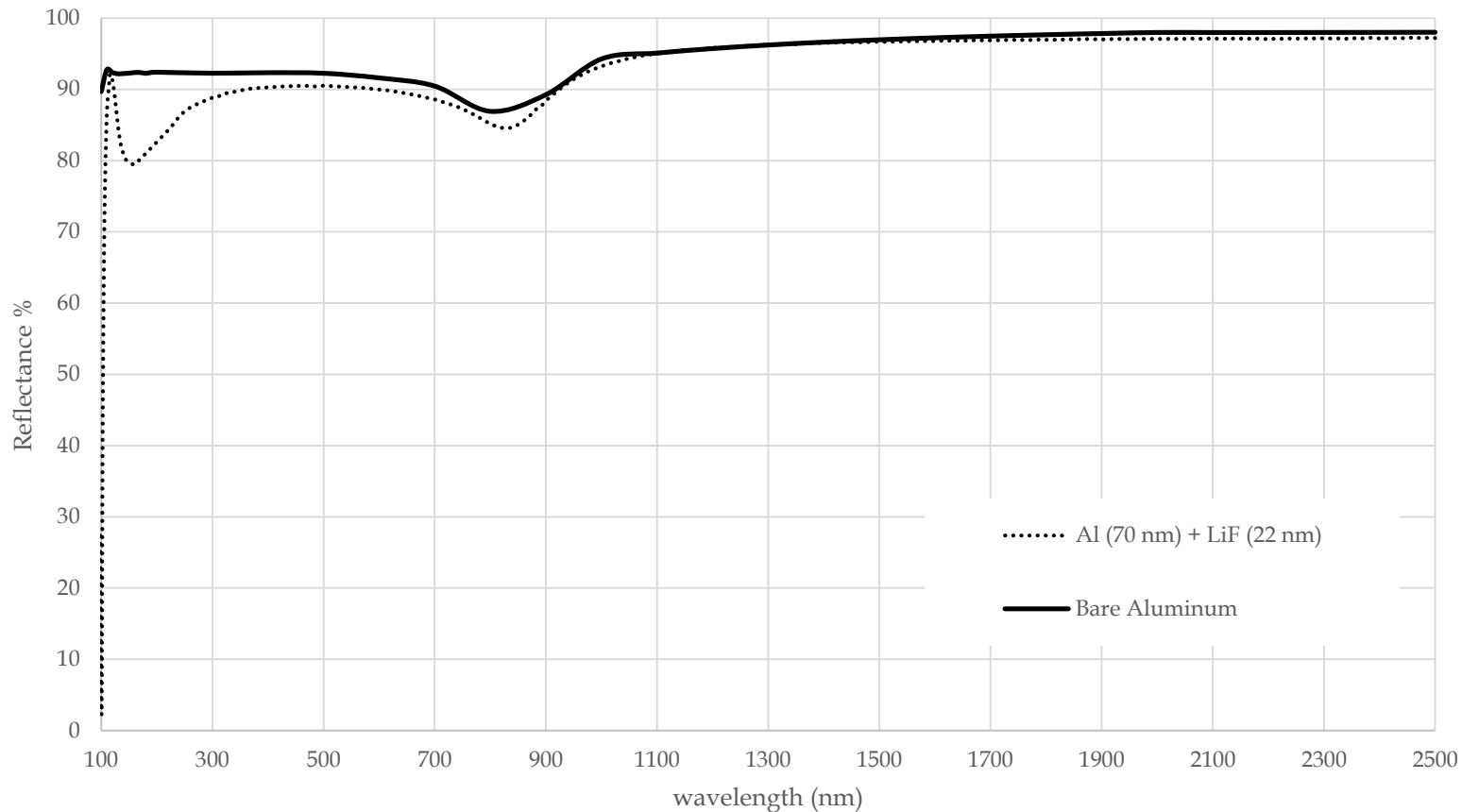
Heating will also be used if compound is not sufficiently reactive for increased selectivity.

XeF_2 is a dry-vacuum based method of reaction and requires no plasma or other activation minimizing damage to substrate.



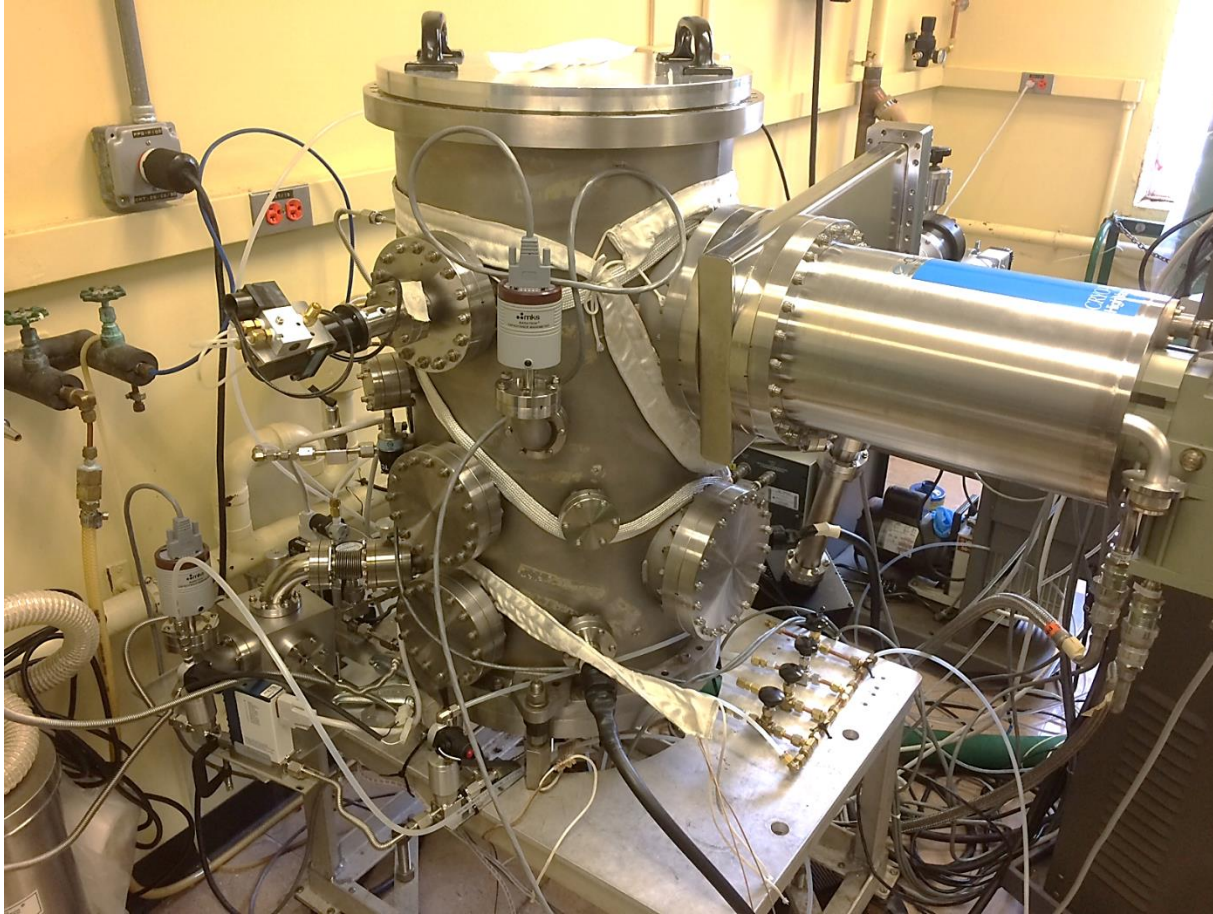
Objective: Oxide-Free Aluminum Mirrors

We propose to develop isotropic/homogeneous protected Aluminum broadband mirror coatings with high performance that will extend from the Far-Ultraviolet (FUV) through the far-infrared wavelengths (90-10,000 nm).





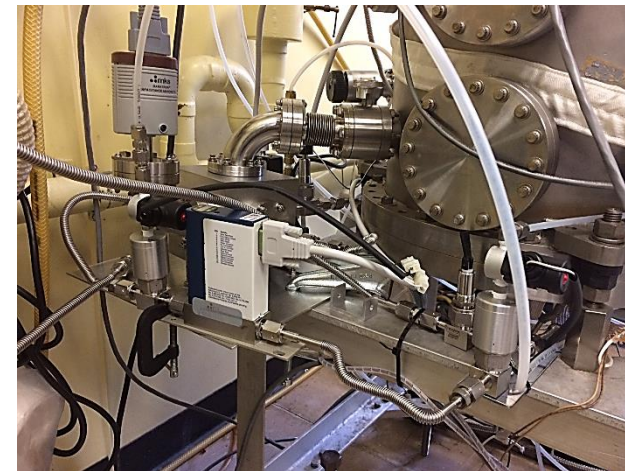
Assembled Research Chamber



UHV Research Chamber capable of thin film physical vapor deposition (PVD) and passivation.

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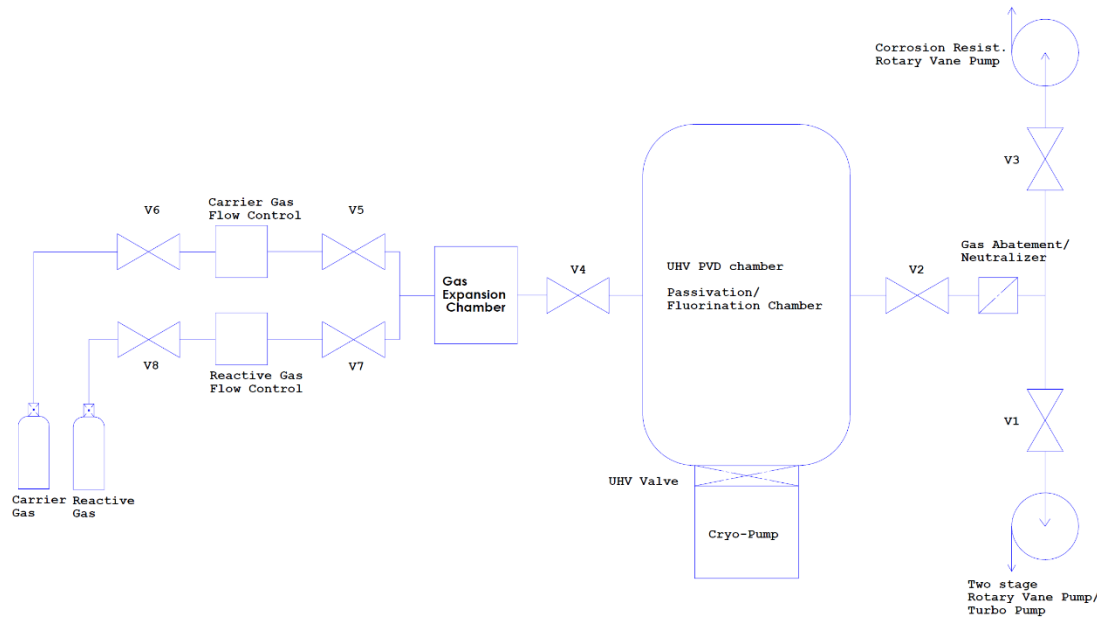
Inside of chamber PVD components.



Gas feed components capable of continuous flow or pulsed flow.



Research Chamber Schematics



Research Chamber for in-situ thermal evaporation and fluorination



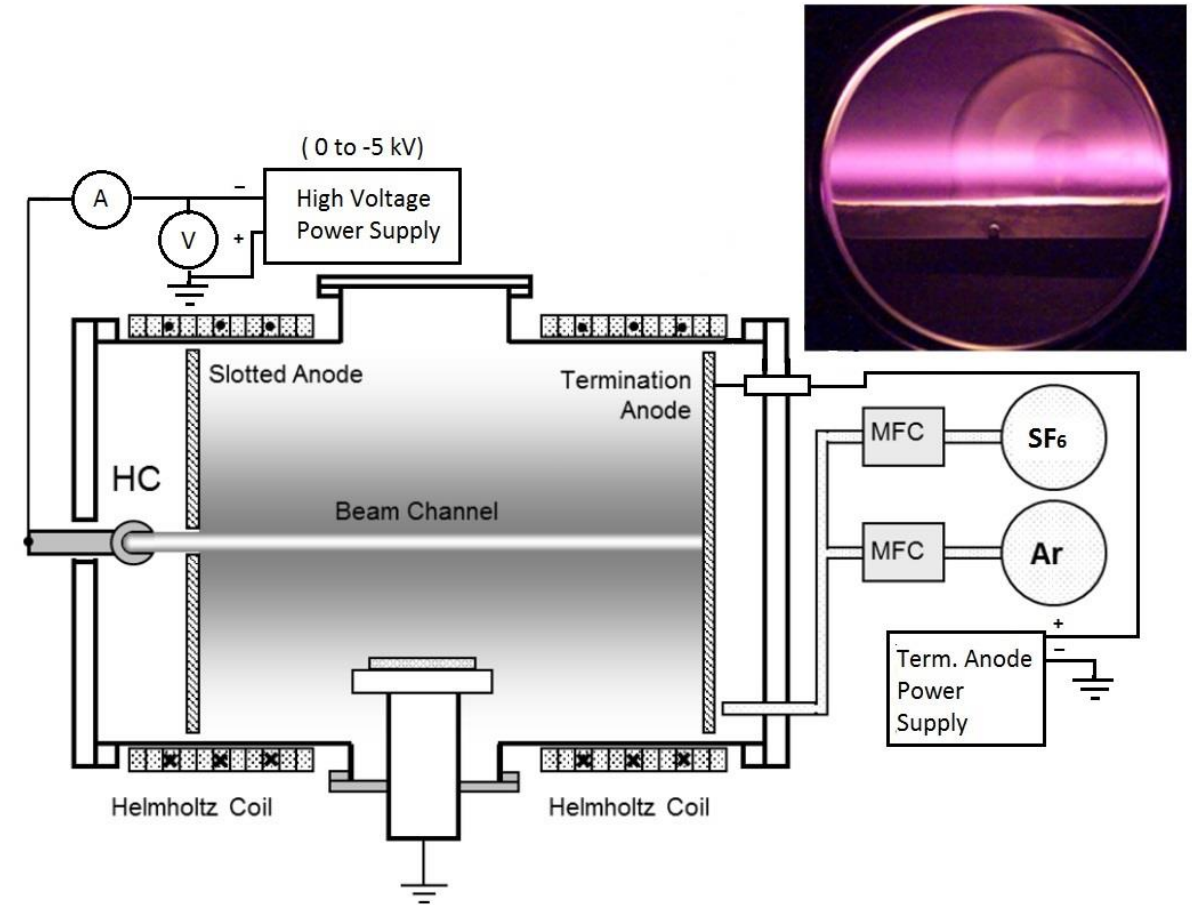
Rack-mounted control/monitor components.



LAPPS Reactor at NRL



- The US Naval Research Laboratory's Large Area Plasma Processing System (LAPPS), which employs an electron beam generated plasma for etching and fluorination of Al samples.
- The schematic diagram illustrates the processing reactor use din this work, whereas the image on the upper right corner is a view of the plasma through a 6 inch port.

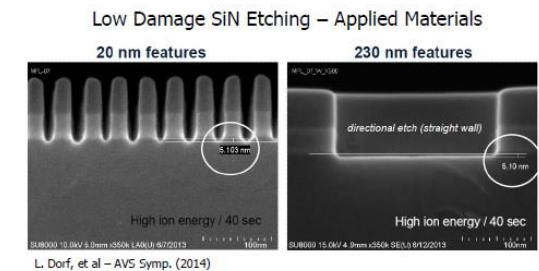
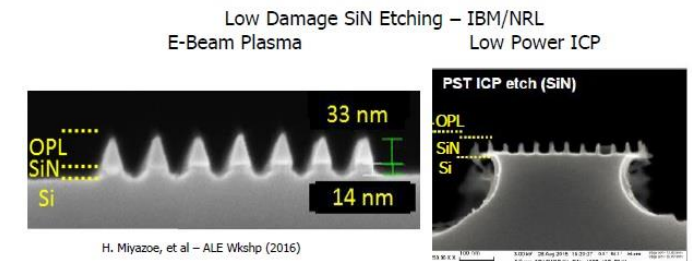
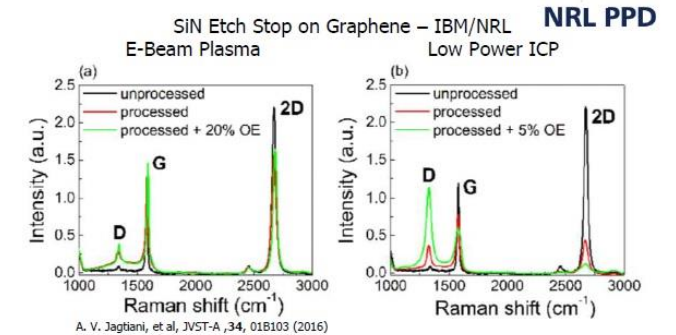




Motivation for e-Beam Etching



- Electron beam generated plasmas have demonstrated the ability to chemically modify 2-D materials while maintaining their unique characteristics.
- Electron beam generated plasmas have shown promise as a low damage etch source. Particularly in processing devices with integrated 2-D materials.
- They have also demonstrated selective, highly directional, low damage etching in SiN without pattern dependent etch characteristics in fluorine based chemistries.
- To understand these results it is important to understand the unique attributes of electron beam generated plasmas.



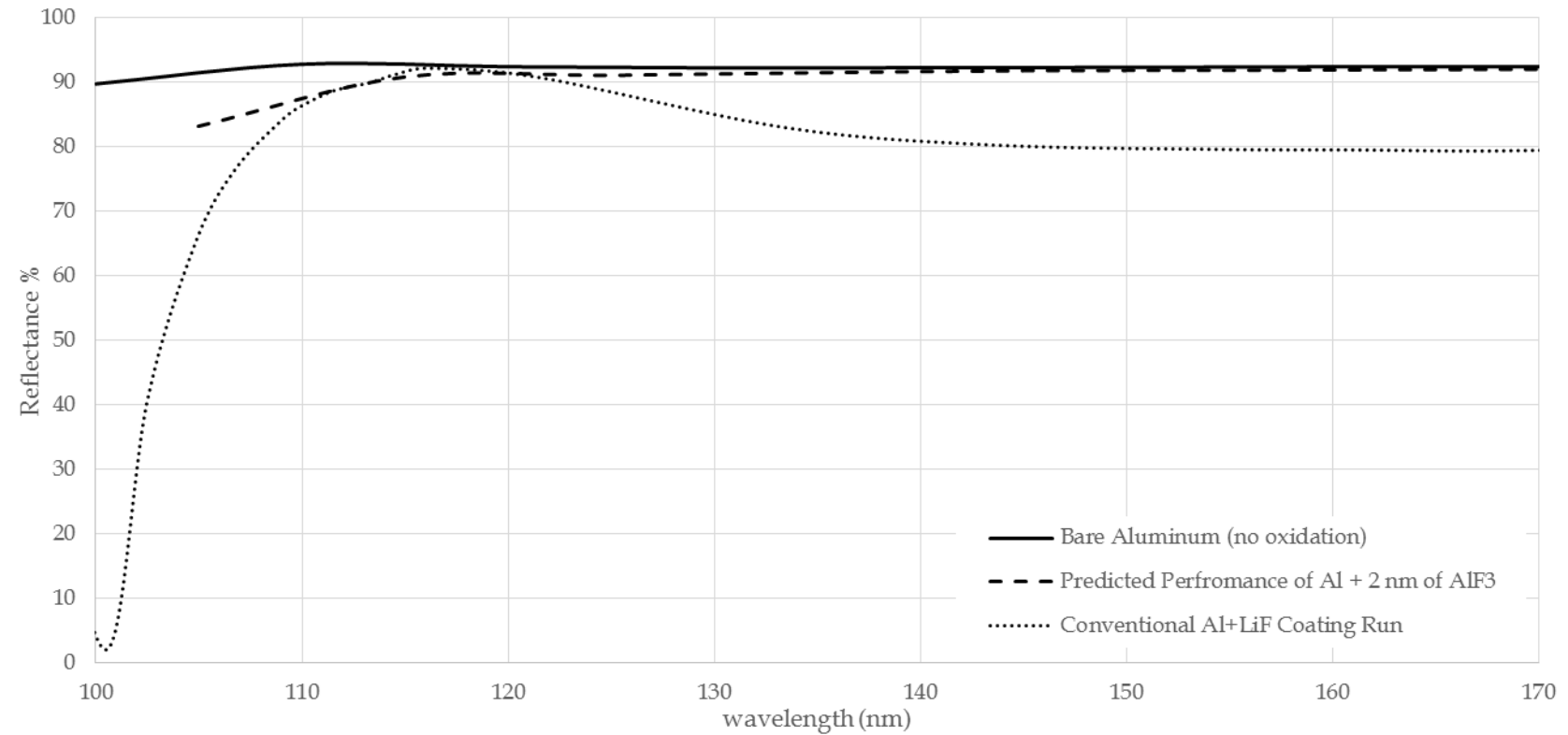


How are e-beam generated?

- The injection of a 2 keV beam into the background gas will directly ionize and dissociate the gas.
- Beam energy well above ionization threshold
- higher beam energy = more efficient ionization



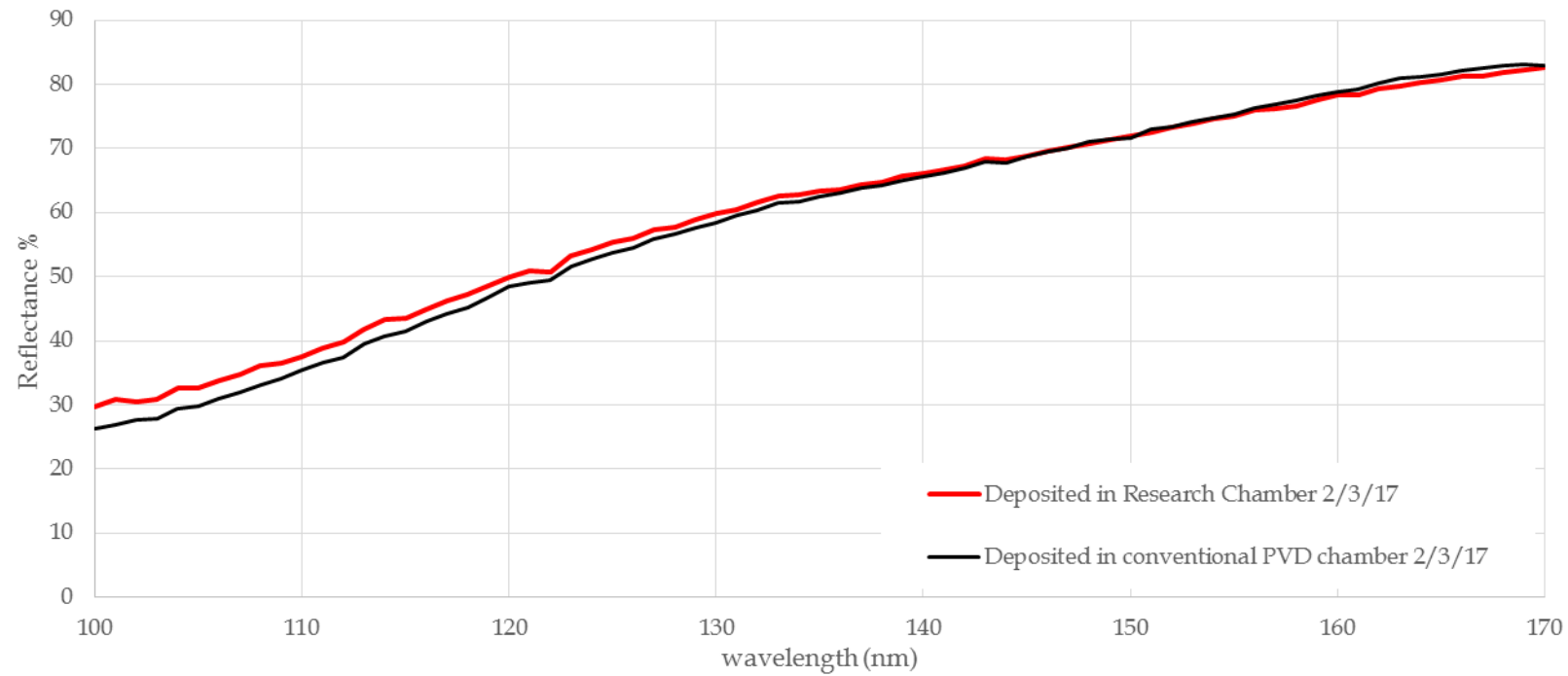
Predicted Performance Comparison



Predicted fluorinated Aluminum should surpass performance of conventional Protective Aluminum coatings

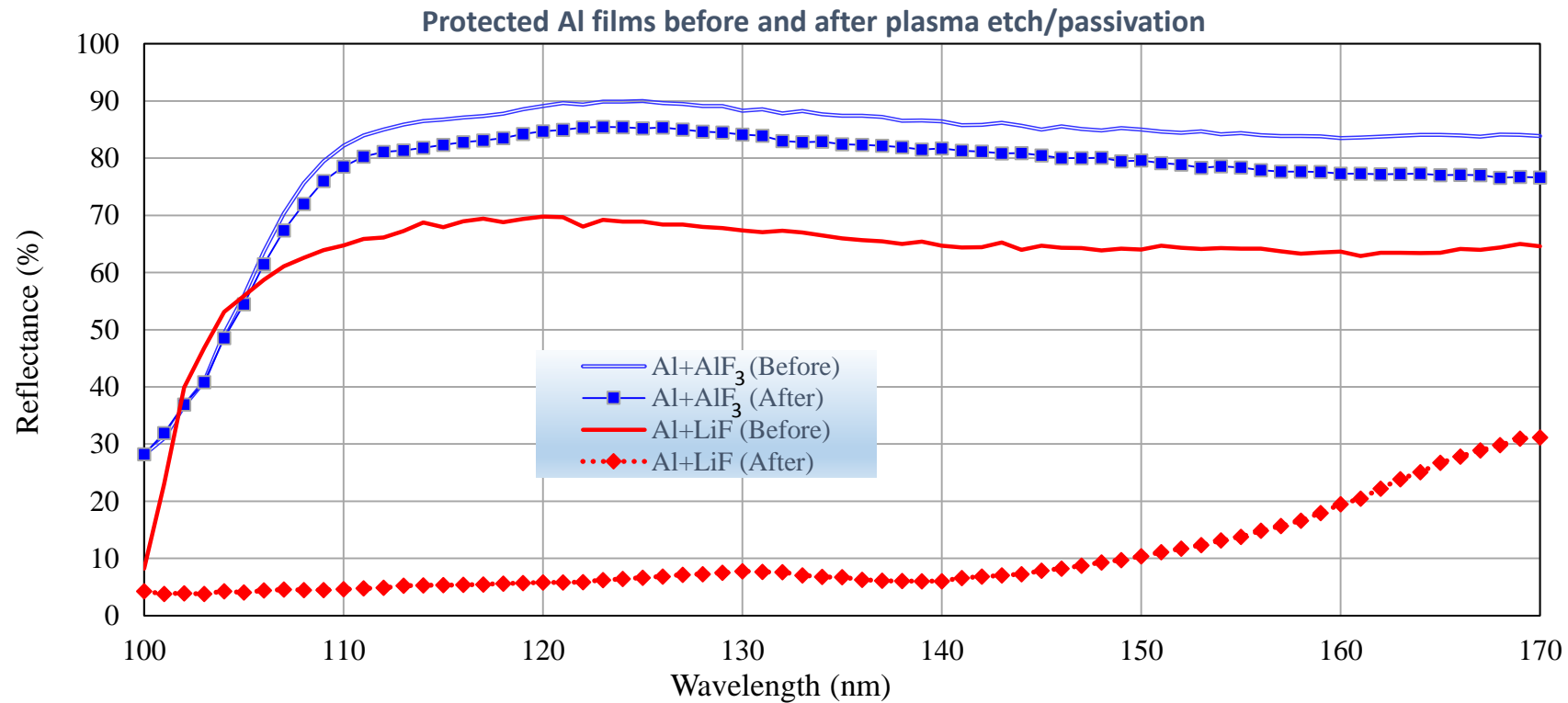


High Performance Aluminum Deposited in Research Chamber





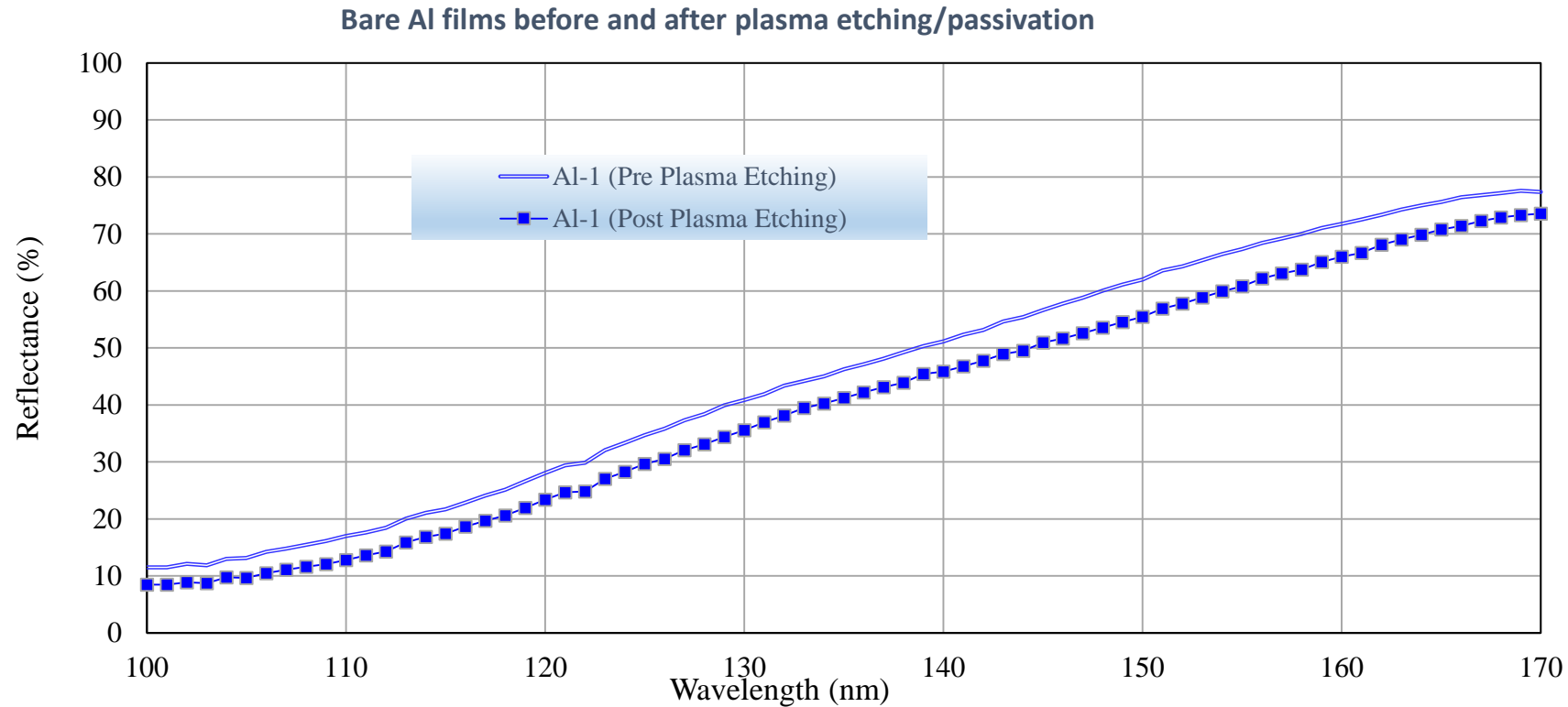
LAPPS E-Beam Results



Reflectance results of Al+AlF₃ and Al+LiF samples before and after treatment in the LAPPS reactor at NRL.



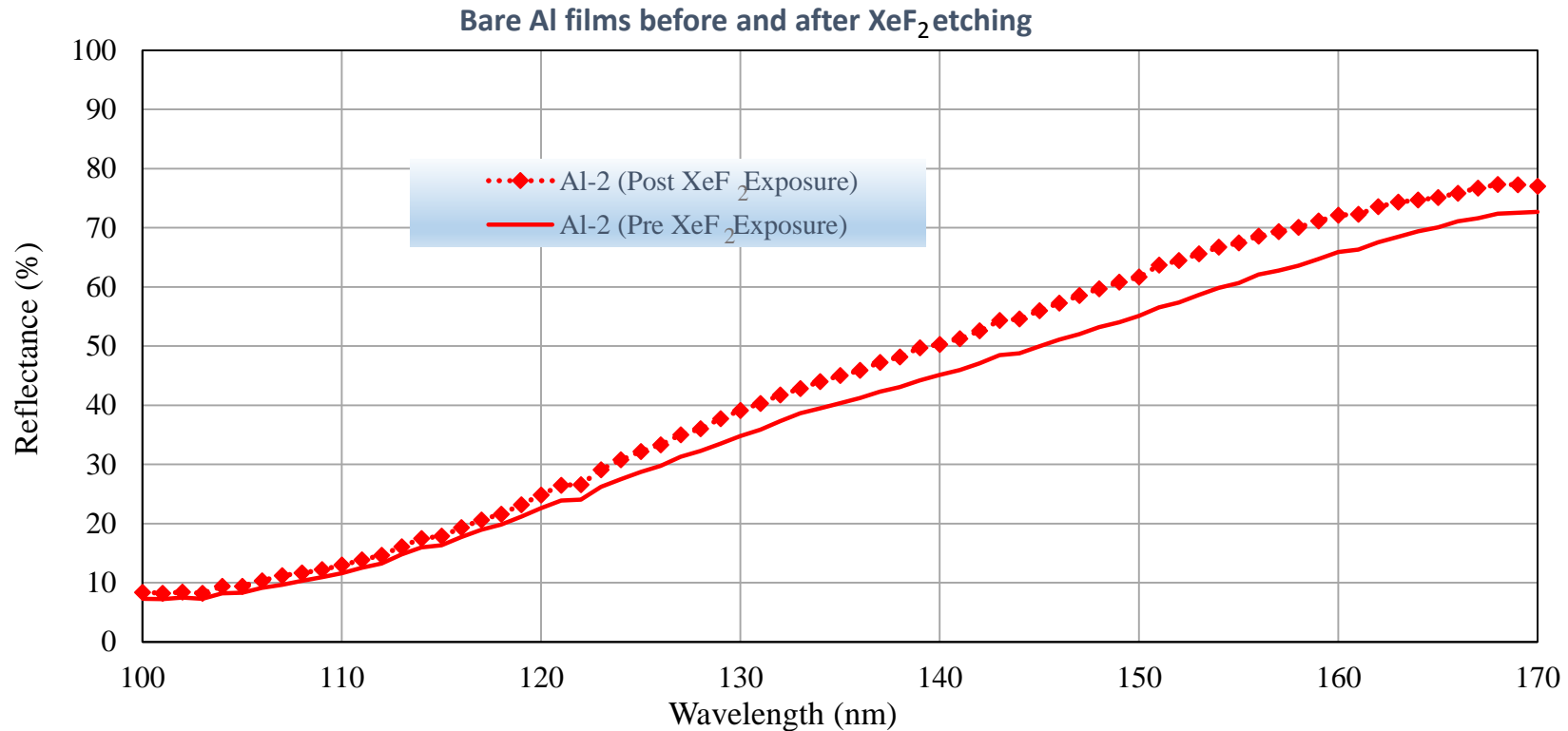
Bare Al e-Beam Etching



Reflectance results of bare Al sample with native oxide layer before and after treatment in the LAPPS reactor at NRL.



Bare Al Before & After XeF₂ Treatment



Reflectance results of bare Al sample with native oxide layer before and after treatment in the XeF₂ reactor located in the Detector Branch (Code 553) at GSFC.



AlF_3 as Aluminum mirror Overcoat

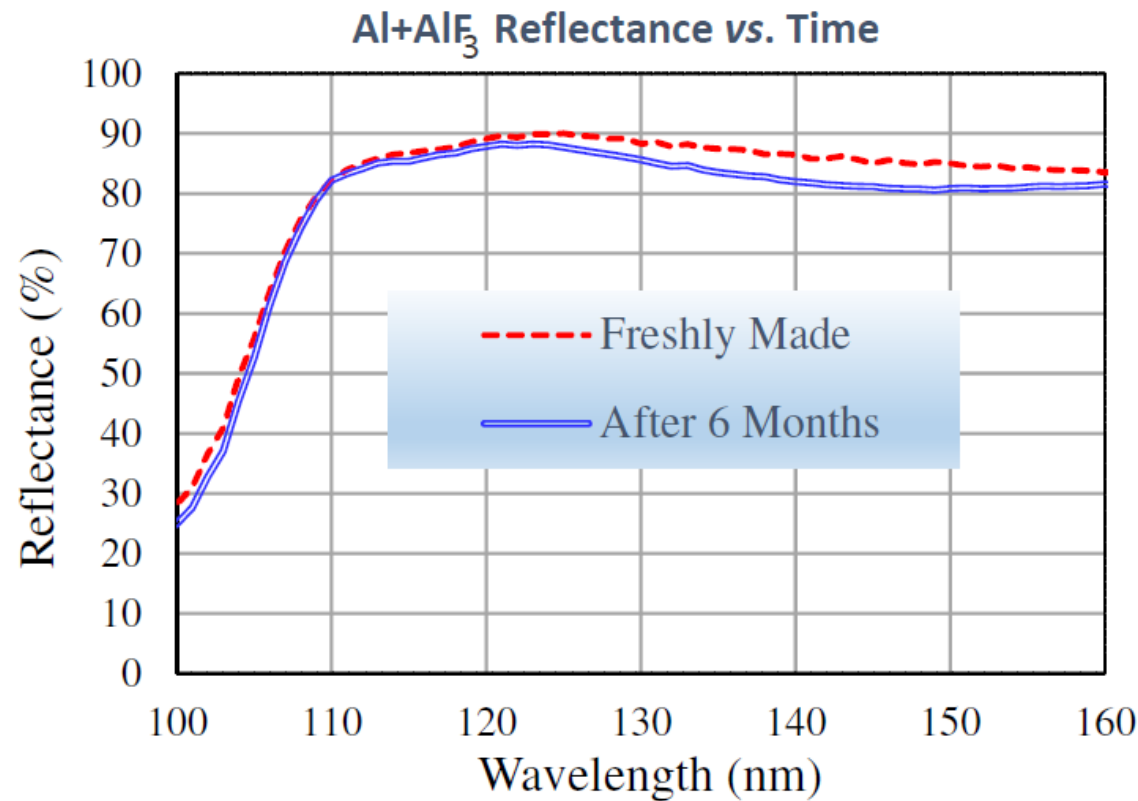
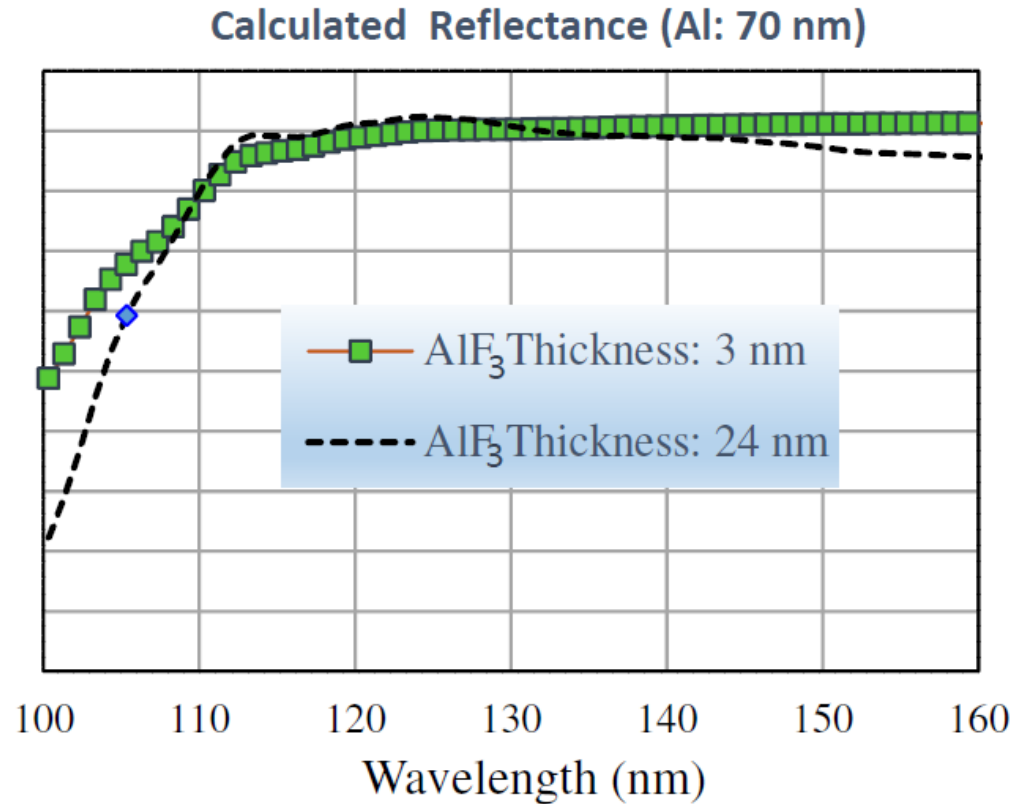


Figure on the left shows the stability in the reflectance of an $\text{Al}+\text{AlF}_3$ sample after it was freshly coated and 6 months later.



The figure on the right shows the predicted reflectance performance for a sample with coating parameters as result shown in figure on the left (Al :70 nm; AlF_3 : 24 nm) in comparison with a much thinner AlF_3 overcoat (3 nm), which will be the AlF_3 thickness for a successfully fluorinated Al sample.



Conclusions

- We studied the feasibility of using the LAPPS reactor (developed at NRL) that employs a low energy- e-beam to etch away the native oxide layer from Al samples as well as thinning the AlF_3 and LiF layers for Al protected with these dielectrics.
- Results indicate no improvement in reflectance performance which may indicate a more aggressive ion or chemical etching would be required for successful native oxide layer removal.
- A second experiment of etching a bare Al sample in a XeF_2 reactor produced a sample with a slight improvement in reflectance in the FUV spectral range.
- Chemical analysis would be conducted in the near future to determine composition of a sample before and after XeF_2 treatment.
- Predicted reflectance performance for a fluorinated Al mirror would produce a sample with reflectance close to 50% at 100 nm and over 90% at wavelengths longer than 110 nm.
- An aluminum sample coated with an AlF_3 overcoat shows a stable reflectance after being kept in a normal laboratory environment (40-50% relative humidity) for a period of 6 months.